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Effect of Iron and Selenium on Growth, Yield and Quality of Eggplant under Different Mineral Fertilization Levels

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ABSTRACT

Eggplant is one of the most important vegetable crops with high nutritional value. So, field experiment was performed to study the effect of foliar application with iron in the form of Fe-EDTA at rate of 300 mg L^{-1} (923.04 g fed^{-1}) and selenium as Na_2SeO_3 (sodium selenite) at rate of 5 mg L^{-1} (4.38 g fed^{-1}) on plant growth, yield, quality and chemical composition of eggplant (*Solanum melongena,* L.) under three levels of nitrogen, phosphorus and potassium fertilization (NPK50%, NPK75% and NPK100% from recommended doses). Field experiment was conducted at Experimental Farm of the Faculty of Agriculture, El-Mansoura University, Dakahlia Governorate, Egypt, in the season of 2016. The used experimental design was a split plot design with three replicates. As for, the treatment NPK fertilizers at rate of 75% from recommended dose with spraying plants by mixture of (Fe + Se) showed the highest significant values of the studied parameters (plant height, number of leaves $plant^{-1}$, leaves fresh and dry weight and total chlorophyll content), yield (fruits length, fruit diameter and yield, except number of fruits $plant^{-1}$ was not significant) at any level of mineral fertilization as well as (N, P and K contents (%) and N, K uptake (g $plant^{-1}$) in eggplant leaves, except P uptake which was non-significant comparing with the untreated plants and fruit quality (crude protein, total carbohydrates, dietary fiber and vitamin C except NO_3^- which gave the opposite trend). The maximum values of NO_3^- concentration in eggplant leaves were obtained by Fe foliar application with NPK-fertilization at rate of 100% RD. On the other hand, the treatment NPK100% x (Fe + Se) as mixture significantly increased the Fe and Se contents in the leaves of eggplant. Accordingly, the application of NPK at rate 75% RD with foliar application of iron and selenium in combination together at rate of 300 mg L^{-1} and 5 mg L^{-1}, respectively gave the highest significant values of all tested characters of eggplant (growth, yield and its quality) under study condition.

Keywords: Eggplant growth, Yield and Quality, NPK fertilizer, Iron, Selenium, Chemical composition, Recommended dose (RD).

INTRODUCTION

Eggplant (*Solanum melongena*, L.) is member of the Solanaecea family; known as Brinjal, Guinea squash or Aubergine (Souza *et al.,* 2018). Eggplant is a traditional vegetable crop, considered as a national diet grown in sub-tropics and tropics region of the world which is broadly cultivated in Egypt, India, Middle East, France and U.S.A (Yousafi *et al.,* 2013).

Eggplant fruits are a good source of proteins, carbohydrates, antioxidant, folate, niacin, vitamins (B1, B6, C), dietary fibers and have mineral composition and being low in calories which is contribute to good human health (El-Nemr *et al.,* 2012). It should increase the productivity and quality of eggplant crop by improving the efficiency of the use of applied fertilizer due to increased demand because of high nutrient content.

Plant nutrition plays an essential role for enhancing yield and quality of eggplant. Mineral fertilizers are very important as a source of the major nutrients for the plant and contribute to the improvement of crop productivity. Nitrogen (N) is considered one of the most important macronutrients that the plants need for their good vegetative growth and yield. Nitrogen fertilization use has played a significant role for synthesis of (chlorophyll, enzymes and protein). The productivity of eggplant is highly positive responsive to N fertilization. Many authors such as Pal *et al.,* (2002); Jilani *et al.,* (2008); Aminifard *et al.,* (2010); Bozorgi (2012) and Azarpour *et al.,* (2012) studied the effects of N fertilizer on growth characters and yield components of eggplant. They concluded that enhancing vegetative growth, fruit yield and yield components traits of eggplant gradually increased with increasing N fertilizer rates. Lima *et al.,* (2014) indicated that growth and yield of eggplant gradually increased with increasing the level of nitrogen up to 150 kg/ha. So, an adequate nitrogen level is therefore very important to increase the production and yield of eggplant.

Phosphorus is an essential nutrient for (phospho-proteins, ATP, ADP formation, phospholipids and root growth). Prabhu *et al.,* (2006) found that increasing N and P doses led to significant increase in total yield.

Potassium plays an essential role in improving the translocation of assimilates, the promotion of enzyme activity and protein synthesis. In addition, many studies have revealed the effect of K in increasing plant growth and fruit quality parameters. Application of higher doses of potassium resulted significant increase in plant growth parameters such as plant length, number of leaves, fruit size, fresh and dry weight of eggplant compared to the control (Fawzy *et al.,* 2007).

Many investigators reported the stimulating effect of applied iron (Fe) and selenium (Se) as foliar spray combined with NPK fertilization rates which can contribute to improve vegetative growth, yield components characteristics and fruit yield of eggplant.

WHO (1996) reported that selenium (Se) is a trace element that is not considered an essential nutrient for plant growth; it is an important element for both animals and humans in trace amounts. Based on the recommendations, a maximum daily intake of Se 200 μg Se/day. The health benefits of Se, which include cancer protection. Selenium is a constituent of seleno-proteins, which have many important functions, including energy metabolism, antioxidant protection, gene expression and redox regulation during transcription. In plants, selenium was indicated to be a component of glutathione peroxidase and play serve a role in anti-oxidative mechanisms. Selenium supplementation to plants indicated to be a component of glutathione peroxidase as shown in tea leaves, increasing antioxidant activity of plants thus, enhances the quality and production of edible plant products. Spraying plants with selenium (Se) solution may enrich the utilizable plant parts with Se compounds in concentrations of nutritional importance (Moussa *et al.,* 2010).

Iron is more important in plant biochemical reactions which can directly or indirectly increases the performance of crops (Zarghamnejad *et al.,* 2015). Fe has a number of important functions within plants, including photosynthesis, respiration and chlorophyll synthesis (Eskandari, 2011). Further, many of metabolic pathways and enzymes are activated by iron. It is suggested to play an important role in growth by stimulating cell division. All plants need a continuous supply of iron during growth because it is not translocate from the mature to developing leaves and is classified as an immobile nutrient element. Many plants are exposed to iron deficiency, which is the result of its effects on reduced nutritional quality and poor yields (Rout and Sahoo, 2015).

Moreover, many investigators reported that fertilized eggplant by micronutrient element (Fe) caused improving plant growth, yield and quality, (El-Nemr *et al.,* 2012; Zarghamnejad *et al.,* 2015; Houimli *et al.,* 2015). They reported that increased and positive effect on the physiological, yield parameters, photosynthetic pigment content and CO_2 assimilation of tomato plant as a result of exposure to plants for increased spraying of iron. Plant height, number of green leaves, fruit number, fruit size, leaf length, fruit weight and yield were significantly increased compared to plants grown under iron-free environment.

Thus, the objective of the present work was to study the effect of different N, P and K fertilizers rates and combined with iron as well as selenium as foliar spraying on the growth characters, yield and its components, fruit quality and chemical composition of eggplant (*Solanum melongena,* L.).

MATERIALS AND METHODS

A field experiment was conducted at the Experimental Farm, Faculty of Agricultural, El-Mansoura University, Dakahlia Governorate, Egypt, during summer season of 2016 in order to find out the effect of foliar application of individual iron (Fe), selenium (Se) and their combination under different levels of NPK fertilization on plant growth characters, yield, quality and chemical composition of eggplant (*Solanum melongena,* L.) cv Black Beauty. The land topography of the experimental site was almost uniform. Prior to planting, soil samples were collected from the soil surface (0-30 cm) of the experimental site for routine analysis, mixed thoroughly to form a composite sample, air dried, sieved by 2 mm sieve and analyzed. The physical and chemical properties of soil were determined according to Chapman and Pratt (1961) and Cottenie *et al.,* (1982). The result indicated the concentration of selenium in the soil was 0.033 mg kg^{-1} for Se. The other results are summarized in Table 1.

A split plot design was used with three replicates in this present study. The levels of mineral fertilizers (NPK 50 %, NPK 75 % and NPK 100 % of recommended dose) were subjected to the main plot and micronutrients foliar application of eggplant was including four different treatments, as follow; 1) untreated (control); 2) Fe in the form of Fe-EDTA at 300 mg L^{-1}; 3) Se in the form of sodium selenite at 5 mg L^{-1}; 4) mixed (Fe + Se) were allotted to sub plots. The amount of foliar solution for one feddan is 400 liter (1 L/plot). The plot size was 3 x 3.5 m; the distance between plants is 20 cm and between rows 70 cm. The experimental unit area was 10.5 m^2, included 4 ridges. Ridges were prepared manually at appropriate height. Thus, the total number of plots used for the study season was 36 plots.

Table 1. Some physical and chemical properties of the soil used during experiment.

Soil characters		Value
Particle size distribution (%)	Coarse sand	4.71
	Fine sand	17.09
	Silt	32.24
	Clay	45.96
	Texture class	Clay
EC, dS m^{-1} (in 1:5 extract)		1.18
pH (in 1:2.5 suspension)		8.09
Saturation percent (%)		57.8
Soil organic matter (g kg^{-1})		16.6
$CaCO_3$ content (g kg^{-1})		23.2
Available nutrient (mg kg^{-1})	N	66.8
	P	7.35
	K	202.6
DTPA extractable (mg kg^{-1})	Fe	2.18

Eggplant (*Solanum melongena,* L.) cv Black Beauty seedlings were planted on the last week of April in the summer season at rate of two seedlings per hole. Plants were later thinned down to one seedling per hole. Spraying treatments were started one month after the planting date and repeated 3 times every 15 days intervals throughout the growing season.

Recommended dose of phosphorus fertilizer as superphosphate (7% P) was fully added to the soil during soil preparation at 26.58 kg P fed^{-1} and potassium fertilization added at rate of 84.32 kg K fed^{-1} as potassium sulfate (40% K) divided into two equal portions were applied one during soil preparation and the other one after one month from planting, Nitrogen fertilization added as ammonium sulfate fertilizer (20.5% N) at rate of 101.6 kg N fed^{-1} divided into three doses, two doses each one after one month as interval from planting and the third dose during flowering stage as shown in Table 2 and Table 2 cont.

All agricultural practices of cultivation were performed as recommended by the Ministry of Agriculture, Egypt.

Table 2. Mineral fertilization rates used in the experiment.

Mineral fertilization Rates	N, kg/fed	P, kg/fed	K, kg/fed
50% NPK from RD	50.8	13.29	42.16
75% NPK from RD	76.2	19.93	63.24
100% NPK from RD	101.6	26.58	84.32

Continue Table 2. Foliar treatments used in the experiment.

Foliar treatments			
Element	Sources		Concentration
Fe	Synthetic Chelate "Fe chelate"	Fe-EDTA as foliar spray	300 mg Fe L^{-1}
Se	Inorganic	Na_2SeO_3 as foliar spray	5 mg Se L^{-1}

Growth parameters and Chemical constituents

The vegetative samples of eggplants were taken after 75 days from transplanting to record vegetative growth parameters on randomly selected five plants in each treatment as follows:

- Plant height (cm).
- Number of leaves $plant^{-1}$.
- Leaves fresh and dry weights (g $plant^{-1}$).

- Total chlorophyll content in leaves, SPAD: Total chlorophyll content of the fifth mature leaf from top was measured as SPAD units using Minolta SPAD-501chlorophyll meter (Minolta Co. Ltd., Japan).

Leaf samples, for nutrient analysis were oven dried at 70 °C for 72 hours till a constant weight, and then fine ground and wet digested. Leaf mineral concentration of N was determined by the microkeldahl decided according to AOAC (2007) and P, K were determined according to Cottenie *et al.,* (1982). Nutrient uptake of leaves in g plant^{-1} equals nutrient content (%) in leaves * dry matter of leaves in (g), Sharma *et al.,* (2012). For determining Fe and Se in plant samples, these elements were measured by using san atomic absorption spectrometer, Kumpulainen *et al.,* (1983).

Yield and fruit quality

Harvesting of the matured fruits of eggplants commenced at 120 days after transplanting every week along with the harvesting season. The following measurements were done:

- Fruit length (cm).
- Fruit diameter (cm).
- Number of fruits plant^{-1}.
- Yield (Mg fed^{-1}).

Fruit quality was determined on the third pick of fruits. Fruit total carbohydrates (%) was determined according to Shumaila and Safdar (2009), fiber (%) were determined according to the method of AOAC (2000) and Vitamin C content in the fruit as mg/100 g fresh weight was estimated according to Mazumdar and Majumder (2003). NO_3^- was determined according to Singh, (1988) Protein content (%) was calculated as follows: N % in fruit x 6.25 according to AOAC (2000)

CoSTATE Computer Software was used to perform statistical analysis of data under study, according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth parameters

A. Effect of NPK fertilizers levels

All growth characters of eggplant (plant height, number of leaves plant^{-1}, fresh weight and total chlorophyll) as influenced by application of different levels of NPK-fertilization are given in Table 3 it was affected significantly but on dry weight was not significant. Mean analysis showed increase of the mean values of vegetative growth characters with increasing NPK doses from 50% up to 100% from recommended dose. The results illustrated that the tallest plants (81.79 cm) were recorded from plots supplied with NPK fertilizers at rate of 100% from RD, followed by (80.61 cm) at rate of 75% from RD, while the lowest plant height (77.55 cm) was recorded at 50% treatment (Table 3). The statistical analysis of the data shows significant differences for no. of leaves plant^{-1}, leaves fresh and dry weight (g) and total chlorophyll regarding NPK fertilizer rates. The maximum values 38.75, 299.2, 67.49 and 1.294 were recorded with NPK fertilizer at rate of 100% from RD for no. of leaves plant^{-1}, leaves fresh and dry weight and total chlorophyll, respectively as compared with 50% treatment. This result could be attributed to the positive effect of nitrogen on eggplant which may be due to the stimulant effects of nitrogen application on vegetative growth characters of eggplant and its known functions in plant life. Also, enzymes, the biological catalytic agents that accelerate life processes, N are involved in many organic compounds of the plant system (Marschner, 1995).

A promotion effect of inorganic fertilizers on chlorophyll content might be attributed to N which is a constituent of chlorophyll molecule or its pigment synthesis in the plant tissues. Similar results have been reported by Zainub *et al.,* (2016) found that increased plant height, days to flowering, days to fruiting, number of leaves plant^{-1}, number of fruits plant^{-1}, fruit weight, total yield and survival percentage of eggplant with increasing rates of NPK fertilizers. As for, P also has a role in improving nitrogen fixation and increasing photosynthesis of plants, while potassium activates some K^+ ions and enzymes that play an important role in control stomatal wait cells of leaves and also increase photosynthesis. Mineral fertilizers NPK improved the dry weight of marketable fruits and yield contributors through better absorption of nutrients, growth and development of pepper plants (Obidiebube *et al.,* 2012). These results agree with those of Jilani *et al.,* (2008), Nafiu *et al.,* (2011), Suge *et al.,* (2011), Oyewole *et al.,* (2014) and Muoneke *et al.,* (2016).

B. Effect of foliar sprays of (Fe & Se).

Results in Table 3 clearly demonstrate that foliar application of chelated iron, sodium selenite singly and in combination together significantly influenced the previous growth parameters as compared to untreated plants. The highest value was noticed with spraying plants by chelated iron + sodium selenite in combination together at rate of 300 mg L^{-1} + 5 mg L^{-1}.

Table 3. Effect of mineral fertilization, foliar application of iron as well as selenium and their interaction on vegetative growth parameters and total chlorophyll of eggplant leaves.

Treatment		Plant height (cm)	No. leaves plant^{-1}	Leaves fresh weight(g)	Leaves dry weight(g)	Total Chlorophyll
A: Mineral fertilizer						
50%NPK		77.55	36.00	287.6	61.43	1.258
75% NPK		80.61	38.25	298.81	66.54	1.282
100%NPK		81.79	38.75	299.2	67.49	1.294
LSD at 5%		1.27	0.86	3.47	6.13	0.01
B: Foliar application						
Untreated		69.23	31.44	256.6	53.05	1.191
Fe		76.41	35.55	286.35	62.57	1.247
Se		83.72	39.66	312.56	68.78	1.308
Fe+Se		90.58	44.00	325.31	76.2	1.366
LSD at 5%		0.77	1.23	3.02	5.08	0.007
Interaction AXB						
50% NPK	Untreated	66.53	30	245.63	44.42	1.171
	Fe	74.06	34	278.90	60.51	1.227
	Se	81.33	38	301.53	66.63	1.287
	Fe+Se	88.30	42	324.33	74.15	1.347
75% NPK	Untreated	69.46	31	256.16	56.30	1.195
	Fe	78.66	36	290.50	64.59	1.269
	Se	86.23	41	323.36	70.93	1.327
	Fe+Se	92.80	46	326.80	78.14	1.387
100% NPK	Untreated	71.70	33	268.00	58.44	1.207
	Fe	76.50	36	289.66	62.63	1.245
	Se	83.60	40	312.80	68.78	1.310
	Fe+Se	90.66	44	324.80	76.31	1.364
LSD at 5%		1.34	2.13	5.23	8.8	0.013

The favorable effect of chelated iron application on growth and leaf chlorophyll content may be due to the role of iron as a cofactor for enzymes involved in a wide variety of oxidation-reduction reactions, i.e., respiration, photosynthesis, DNA synthesis and hormone synthesis. This function makes iron an essential nutrient for the development and reproduction of plants, thereby enhance the plant growth and chlorophyll content. These results are in line with Houimli *et al.,* (2015). Regarding the effect of selenium, the results showed significant positive effect at Se 5 mg L^{-1} level for plant height, no. of leaves plant^{-1}, leaves fresh and dry weight and total chlorophyll. These results can be explained on this basis; the increases in chlorophyll content in eggplant leaves at this level of sodium selenite may be attributed to selenium overprotection effect of chlorophyll enzymes and thus, increasing the biosynthesis of photosynthesis pigments. The data are in a good harmony with those obtained by Saffaryazdi *et al.,* (2012); Nancy and Arulselvi (2014) and Mozafariyan *et al.,* (2017) who stated that at Se application at rate of 7 and 10 µM Se levels, increased chlorophyll content.

C. The interaction effect between NPK levels and foliar sprays of (Fe & Se).

The interaction effect of mineral fertilizers x foliar application of (Fe + Se) combined together was better than that of (mineral fertilizers x chelated iron) or (mineral fertilizers x sodium selenite) which gave the highest significant effect on plant height, no. of leaves plant^{-1}, leaves fresh and dry weight and total chlorophyll (Table 3). The treatment of NPK 75% x (Fe + Se) showed the greatest values of measured parameters during the season compared with the other treatments. This may be due to nitrogen availability from the inorganic fertilizer. Therefore, increasing nitrogen levels increased multiplication of cells which enhances the amount of metabolites necessary for building plant organs and consequently the vegetative growth of plants while, the increment in plant growth due to P could be interpreted as a reflection to its role in photosynthesis, root proliferation and growth, cell division and enlargement and energy storage. These results are in accordance with the findings of Bozorgi (2012) ; Yassen *et al.,* (2011) who studied the effect of both N fertilizer at rates of (0, 150, 200 and 250 kg N fed^{-1}) and selenium spray at rates of (0, 20, and 40g fed^{-1}) on the vegetative growth. Results showed that the interaction effects between N rates and selenium application significantly promoted growth parameters compared with nitrogen and/or Se alone treatments, with respect to all growth characters.

Yield and its components

A. Effect of NPK fertilizers levels

Data in Table (4) show the effect of rates of NPK fertilizers as well as foliar application of Fe, Se and (Fe + Se) in combination and their interaction between mineral fertilization on yield parameters of eggplant. Results showed significant differences in various yield characters. Regarding the main effects of rates of NPK fertilization on yield and its component, the results given in Table 3 reflect that increasing the application of NPK fertilization to the grown plants, from 50% up to 100% from RD, significantly increased all the studied yield and its components, except number of fruits plant^{-1} was not significant. The results illustrate also that the high significant mean values of fruit length, fruit diameter, number of fruit plant^{-1} and total yield 19.21 cm, 5.91 cm, 25.25 and 31.31 Mg fed^{-1} were given by application of NPK at rate of 100% RD, respectively, in the growing season. The results demonstrate that significant increase in various yield characters values (except number of fruits plant^{-1} was not significant at any levels of NPK fertilization) was recorded with increasing NPK doses in treated plots from 50% up to 100 % from RD. These results generally show that the use of high levels of nitrogen has led to eggplant response well, and has the best performance for all the characters studied. More values of number of fruits plant^{-1} are associated with the vegetative growth of plant. Hence, the presence of nitrogen is responsible for the vegetative growth of plants and hence caused more no. of leaves (food factory), which creates a larger no. of fruits plants^{-1} ultimately (Roychaudhury *et al.,* 1995). These results are in good agreement with those obtained by Bobadi and Damme (2003); Jilani *et al.,* (2008); Suge *et al.,* (2011); Oyewole *et al.,* (2014) and Muoneke *et al.,* (2016). Who indicates that increasing application of N fertilization level increased fruit length, fruit diameter, no. of flowers plant^{-1} fruit, weight and the yield of eggplant. The additive of nitrogen was strongly and positively related to the physiological and nitrogen recovery efficiency as well as the harvest index (Kostadinov and Kostadinova, 2014).

B. Effect of foliar sprays of (Fe & Se)

The results obtained in the present study showed a significant increase in fruit length, fruit diameter, no. of fruit plant^{-1} and total yield in chelated iron spraying in combination with Se (Table 4). The maximum values were found at 300 mg L^{-1} of Fe-EDTA + 5 mg L^{-1} sodium selenite Na_2SeO_3. However, eggplant showed the minimum response to the untreated treatment. This might be due to the fact, that iron has a major role in the process of photosynthesis, which is the component of chlorophyll, which is the main constituent of green matter in the plant and has a major role in the processes of oxidation and reduction within the plant and respiration process. The ability to photosynthesize and produce more food increase the generative power, enabling plants to hold more fruits (Kazemi, 2013), thereby increase the yield and its component. In the present study the effect of Fe-chelated on eggplant yield and its components may be due to the effect of chelated iron in leaf content of nutrient element (Table 5), which reflected on growth and chlorophyll content of plant (Table 3) and finally led to an increase of the yield and its components of eggplant (Table 3). The above results are in conformity with the findings of (Kazemi, 2013 and Houimli *et al.,* 2015) and Germ *et al.,* (2005) who observed that application of 1.5 mg L^{-1} Se into the zucchini plants increased the yield.

C. The interaction effect between NPK levels and foliar sprays of (Fe & Se)

From the obtained data shown in Table 4, yield and its components of eggplant significantly increased with increasing NPK fertilization under foliar applications of iron + selenium. The best fruit length, fruit diameter, number of fruit plant^{-1} and total yield values were recorded at the treatment of NPK fertilizers at the rate of 75 % from recommended doses and sprayed with (Fe + Se) together. These results are in harmony with these of Yassen *et al.,* (2011) and Bozorgi, (2012).

Table 4. Effect of mineral fertilization, foliar application of iron as well as selenium and their interaction on yield and its components of eggplant.

Treatment		Fruit Length, cm	Fruit diameter, cm	No. fruits plant^{-1}	Yield (Mg fed^{-1})
A: Mineral fertilizer					
50%NPK		17.78	5.53	23.83	29.76
75% NPK		18.98	5.80	24.75	30.87
100%NPK		19.21	5.91	25.25	31.31
LSD at 5%		0.41	0.02	1.40	0.30
B: Foliar application					
Untreated		15.04	4.76	20.44	26.63
Fe		17.58	5.42	23.33	29.34
Se		19.80	6.08	25.44	32.05
Fe+Se		22.17	6.72	29.22	34.54
LSD at 5%		0.59	0.08	1.33	0.13
Interaction AXB					
50% NPK	Untreated	14.26	4.55	20.00	25.74
	Fe	16.53	5.21	22.33	28.42
	Se	18.96	5.85	24.00	31.20
	Fe+Se	21.33	6.52	29.00	33.65
75% NPK	Untreated	15.10	4.76	20.33	26.63
	Fe	18.20	5.64	24.00	30.26
	Se	20.56	6.31	26.66	32.89
	Fe+Se	22.96	6.93	30.00	35.43
100% NPK	Untreated	15.76	4.98	21.00	27.51
	Fe	18.03	5.42	23.66	29.35
	Se	19.86	6.07	25.66	32.06
	Fe+Se	22.23	6.73	28.66	34.56
LSD at 5%		1.03	0.15	2.31	0.23

Chemical constituents (N, P and K contents and uptake).

A. Effect of NPK fertilizers levels

The experimental results showed that N, P and K contents (%) and nutrients uptake (g plant^{-1}) by eggplant leaves were statistically affected by different rates of applied NPK fertilization (Table 5). N-P-K fertilizers rates significantly ($P \leq 0.05$) increased N, P and K contents (%) and uptake (g plant^{-1}) in eggplant leaves. Statistically higher nitrogen, phosphorous and potassium contents (%) were (1.78, 0.195 and 1.97 %), respectively and the maximum uptake of NPK (123.65, 13.49 and 136.78 g plant^{-1}) was found in treatment which received 100% NPK from recommended dose and differ from rest of the treatments during the season and was the lowest in 50% NPK from RD treatment as shown in Table 5.

These increase due to the availability of the elements of nitrogen, phosphorus and potassium in the soil for plant, which lead to an increase in root growth, so, improving the absorbing area of root. This result agree with Baddour, (2010) who found that NPK treatment applied at 50 to 75% from RD and, fatherly to 100% significant increased leaf-NPK contents of tomato plants. Also, El-Hamady *et al.,* (2017) who showed that N, P and K uptake by eggplant leaves significantly increased with increasing NPK rates.

B. Effect of foliar sprays of (Fe & Se)

As shown in Table 3, foliar application treatments had a significant effect comparing with the untreated plant on nitrogen, phosphorus and potassium content and uptake by eggplant leaves. It is obvious that the highest significant values of nitrogen, phosphorus and potassium (%) and uptake (g plant^{-1}) by eggplant leaves were recorded with foliar application of (Fe + Se) in combination together. These findings may be due to the enhancement of N, P, and K concentrations and uptake as a result of using this foliar application of (Fe + Se) and are in agreement with those recorded by El-Hamady *et al.,* (2017). Application of Fe and Se has been reported to have significant positive effects, in most cases, on growth measurements and chemical composition. These results are in harmony with those found by Ruchi and Sharma (2004), El-Bassiony *et al.,* (2006) and Yassen *et al.,* (2011) who found that the selenium foliar application treatment on potato plants recorded the best nitrogen, phosphorus and potassium and protein contents in in the yield of tubers of potato plants. In general, increasing leaves and fruits nutrient contents and uptake by eggplant with increasing foliar Se supplements may be due to the role of Se in increasing antioxidant activity of the plant and the role of Fe in improving plant growth, yield, quality and chemical composition.

C. The interaction effect between NPK levels and foliar sprays of (Fe & Se)

Concerning N, P and K contents (%) and uptake by eggplant leaves, data in Table 5 illustrate that the interaction between NPK fertilizer levels treatment and foliar application treatments had a significant effect on N, P and K contents (%) and a significant effect on N and K uptake (g plant^{-1}) by eggplant leaves, except for P uptake which was non-significant.

Table 5. Effect of mineral fertilization, foliar application of iron as well as selenium and their interaction on N, P and K contents (%) and uptake (g plant^{-1}) by eggplant leaves.

Treatment		N %	N Uptake (g plant^{-1})	P %	P Uptake (g plant^{-1})	K %	K Uptake (g plant^{-1})
A: Mineral fertilizer							
50%NPK		1.58	101.24	0.176	11.26	1.75	112.07
75% NPK		1.73	117.68	0.190	12.88	1.89	128.85
100%NPK		1.78	123.65	0.195	13.49	1.97	136.78
LSD at 5%		0.053	7.42	0.004	0.64	0.024	6.80
B: Foliar application							
Untreated		1.17	62.77	0.137	7.38	1.333	71.16
Fe		1.53	95.89	0.171	10.74	1.693	106.12
Se		1.88	129.71	0.203	14.01	2.066	142.32
Fe+Se		2.20	168.39	0.236	18.05	2.412	183.99
LSD at 5%		0.031	5.79	0.003	0.75	0.033	6.54
Interaction AXB							
50% NPK	Untreated	1.04	46.09	0.126	5.65	1.216	53.71
	Fe	1.42	86.13	0.160	9.72	1.583	95.82
	Se	1.76	117.51	0.194	12.93	1.946	129.71
	Fe+Se	2.09	155.23	0.225	16.73	2.280	169.06
75% NPK	Untreated	1.17	66.25	0.138	7.79	1.340	75.44
	Fe	1.64	106.13	0.181	11.71	1.816	117.33
	Se	1.98	140.93	0.214	15.18	2.186	155.11
	Fe+Se	2.32	181.29	0.247	19.30	2.550	199.25
100% NPK	Untreated	1.30	75.98	0.149	8.70	1.443	84.34
	Fe	1.52	95.40	0.172	10.79	1.68	105.22
	Se	1.90	130.69	0.202	13.91	2.066	142.16
	Fe+Se	2.21	168.65	0.237	18.13	2.406	183.67
LSD at 5%		0.053	10.04	0.006	1.31	0.057	11.34

The results illustrated that the increment of N, P and K contents and uptake by eggplant leaves were obtained when plants received fertilizers level 75% RD combination with sprayed with the mixture of (Fe + Se). While, the lowest N, P and K contents and uptake were obtained in the plots received fertilizers level 50% RD without microelements. These results are in harmony with those of Erdoğan *et al.,* (2010) and Yassen *et al.,* (2011).

Chemical constituents (Fe and Se contents)

A. Effect of NPK fertilizers levels

Data in Table (6) show that Fe concentration in the leaves of eggplant were significantly increased with applied NPK fertilizers levels, but Se concentration was not significant in the growing season. The maximum Fe concentration (32.45 mg kg^{-1}) was recorded in treatment which fertilized with 100% NPK from RD and the lowest was recorded in 50% NPK treatment (31.52 mg kg^{-1}). The Se concentration was the highest (0.17 mg kg^{-1}) in treatment 100% NPK from RD and the lowest in 50% NPK treatment (0.09 mg kg^{-1}). In this direction, El-Hamady *et al.,* (2017) they found that NPK100% treatment significantly increased Se content in sweet pepper plant.

Table 6. Effect of mineral fertilization, foliar application of iron as well as selenium and their interaction on Fe and Se contents (mg kg^{-1}) in eggplant leaves.

Treatment		Fe (mg kg^{-1})	Se (mg kg^{-1})
A: Mineral fertilizer			
50%NPK		31.52	0.09
75% NPK		31.94	0.13
100%NPK		32.45	0.17
LSD at 5%		0.44	0.12
B: Foliar application			
Untreated		30.62	0.13
Fe		33.32	0.10
Se		31.52	0.16
Fe+Se		32.43	0.14
LSD at 5%		0.32	0.10
Interaction AXB			
50% NPK	Untreated	30.31	0.05
	Fe	32.11	0.08
	Se	31.25	0.11
	Fe+Se	32.44	0.13
75% NPK	Untreated	30.62	0.06
	Fe	32.09	0.10
	Se	31.48	0.14
	Fe+Se	33.58	0.17
100% NPK	Untreated	30.92	0.07
	Fe	33.10	0.12
	Se	31.83	0.16
	Fe+Se	33.95	0.19
LSD at 5%		0.55	0.17

B. Effect of foliar sprays of (Fe & Se)

Data in Table 6 illustrate that different foliar application treatments caused a clear increments and a significant increase was found in Fe content (mg kg^{-1}) in eggplant leaves, but Se content was not significant. The higher values of iron and selenium were recorded when the plant sprayed with Fe and Se individually, respectively followed by the mixture of them together compared with untreated plants. Control treatment recorded the lowest value with significance when compared to the other treatments. Application of Fe and Se as a sublimentaion sources by spraying is more effective for absorption of elements through leaves. Similar results were obtained by Fernandez, (2007).

C. The interaction effect between NPK levels and foliar sprays of (Fe & Se)

Concerning the interaction between NPK fertilization rates and foliar spray of chelated iron and sodium selenite in Table 6, data showed non-significant effect of Fe and Se contents in eggplant leaves. 100% NPK with foliar application of (Fe + Se) in combination together, resulted better concentrations of Fe and Se in the leaves of eggplant plant.

Quality of fruits

A. Effect of NPK fertilizers levels

Concerning the effect of NPK fertilization rats on the fruits quality of eggplant, the results shown in Table (7) indicated that crude protein, total carbohydrates, dietary fiber, vitamin C and NO_3^- in eggplant fruits are significantly increased with increasing NPK fertilizers rates up to 100% from RD. The maximum values were obtained with the recommended NPK treatment (NPK100%) 5.88%, 24.90%, 13.57%, 4.09 mg $100g^{-1}$ and 43.43 mg kg^{-1} for C. protein, T. carbohydrates, D. fiber, V.C and NO_3^- in fruits, respectively compared with the lowest treatment. These results may be due to increased availability and better use of nutrients at higher nitrogen, phosphorus and potassium levels. These results corroborate the findings of Suge *et al.,* (2011) who observed that increased levels of nitrogen, phosphorus and potassium from 50% up to 100% from RD, improved fruit quality in eggplant. It was noticed that increasing availability of adequate amount of nutrients in the soil increases the nutrient absorption, this implied having improved dry matter production, and therefore eggplant is one of the most important plants with high nutritional value with adequate fertilizer application. This invariably improving the quality of the crop economic products. The obtained results are; generally, agreement with those of Nafiu *et al.,* (2011) and Lawal *et al.,* (2015). Also, improving effect application of NPK on crud protein and carbohydrates contents may be attributed to its role in synthetic in activating many enzymes in plant. Such enzymes act as catalyst for synthesis of protein and starch.

B. Effect of foliar sprays of (Fe & Se)

From the data recorded in Table (7), it is obvious that spraying with both (Fe + Se) significantly increased the values of C. protein, T. carbohydrates, D. fiber and V.C in fruits of eggplant plant compared to the untreated plant, followed by reduction in results values with foliar application as following Se > Fe individually, sequentially. On the other hand, NO_3^- gave an opposite trend, so as spraying with selenium alone significantly depressed the values of these parameters. The maximum values of NO_3^- concentration in eggplant leaves were obtained by Fe foliar application 41.29 mg Kg^{-1}. The data are in a good harmony with those obtained by Mozafariyan *et al.,* (2017) who stated that increasing the concentration of selenium up to 10 µM led to a decrease the membrane stability index. In addition, raising levels of selenate or selenite decreased Se accumulation inside algal cells, maybe through repression of membrane transporters (Schiavon *et al.,* 2016). Also, similar results were obtained by Nancy and Arulselvi (2014).

C. The interaction effect between NPK levels and foliar sprays of (Fe & Se)

With respect to the effect of interaction between NPK fertilizers rates treatment and foliar application treatments on the previous parameters in eggplant fruits, it is noticed from the data presented in Table 7 that results showed significant positive effects on all fruit quality parameters in eggplant fruits. The highest values of the parameters were achieved when the mixture of (Fe + Se) was foliar sprayed on plants fertilized with NPK-fertilization at 75% RD except NO_3^- which gave opposite trend comparing with other treatments. The maximum values of NO_3^- concentration in eggplant leaves were obtained by Fe foliar application 55.53 mg Kg^{-1} with NPK-fertilization at rate of 100% RD.

Table 7. Effect of mineral fertilization, foliar application of iron as well as selenium and their interaction on eggplant quality fruits.

Treatment		[1]C. protien (%)	[2]T. Carbohydraties (%)	[3]D. Fiber (%)	[4]V.C (mg/ 100g)	NO_3-N (mg kg^{-1})
A: Mineral fertilizer						
50%NPK		5.48	24.38	13.29	3.86	35.27
75% NPK		5.74	24.76	13.49	4.03	36.44
100%NPK		5.88	24.90	13.57	4.09	43.43
LSD at 5%		0.33	0.20	0.10	0.04	1.58
B: Foliar application						
Untreated		4.62	23.25	12.72	3.41	42.87
Fe		5.34	24.19	13.20	3.80	41.29
Se		6.09	25.19	13.69	4.18	28.90
Fe+Se		6.75	26.11	14.18	4.59	40.47
LSD at 5%		0.32	0.14	0.07	0.04	4.89
Interaction AXB						
50% NPK	Untreated	4.40	22.95	12.56	3.29	40.20
	Fe	5.11	23.87	13.04	3.67	33.62
	Se	5.84	24.86	13.53	4.05	24.92
	Fe+Se	6.56	25.85	14.02	4.46	36.93
75% NPK	Untreated	4.63	23.24	12.73	3.41	41.66
	Fe	5.59	24.51	13.36	3.92	34.72
	Se	6.34	25.51	13.86	4.30	30.35
	Fe+Se	6.98	26.36	14.34	4.75	37.97
100% NPK	Untreated	4.85	23.55	12.88	3.55	46.75
	Fe	5.34	24.18	13.21	3.81	55.53
	Se	6.08	25.19	13.69	4.19	31.42
	Fe+Se	6.71	26.12	14.19	4.56	46.51
LSD at 5%		0.56	0.24	0.12	0.07	8.48

[1]Crude protein; [2]total carbohydrate; [3]dietary fiber, [4]vitamin C

CONCLUSION

On the basis of this investigation, it is concluded be concluded that the eggplant (*Solanum melongena,* L.) responded well to NPK fertilization, foliar application of micronutrients, iron in the form of Fe-EDTA (chelated iron) and selenium in the form of Na_2SeO_3 (sodium selenite) and enhanced most of the growth and yield attributes of eggplant cv Black Beauty. Thus, the obtained results from this study emphasized that the best treatment was addition of NPK at 75% from recommended dose and using mixture of iron (300 mg L^{-1}) + selenium (5 mg L^{-1}) as foliar application, which gave the best results and the optimum values for growth, yield components and quality of eggplant except NO_3^- which gave opposite trend comparing with other treatments. The maximum values of NO_3^- concentration in eggplant leaves were obtained by Fe foliar application with NPK-fertilization at 100% RD.

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تأثير الحديد والسيلينيوم علي نمو وانتاج وجودة الباذنجان تحت مستويات مختلفة من التسميد المعدني

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الباذنجان واحد من أهم محاصيل الخضر ذات القيمة الغذائية العالية. لذا أقيمت تجربة حقلية لدراسة تأثير الرش بالحديد علي صورة حديد مخلبي , حديد اديتا بتركيز ٣٠٠ ملجم لتر-١ (٩٢٣.٠٤ جرام فدان-١) والسيلينيوم علي صورة سلينات صوديوم بتركيز ٥ ملجم لتر-١ (٤.٣٨ جم فدان-١) علي نمو النبات والمحصول وجودة والتركيب الكيميائي لنبات الباذنجان تحت تأثير ثلاث مستويات من التسميد المعدني (٥٠٪ NPK ، ٧٥٪ NPK و ١٠٠% NPK من الجرعة الموصى بها). نفذت تجربة حقلية في مزرعة كلية الزراعة , جامعة المنصورة , محافظة الدقهلية, مصر, موسم ٢٠١٦. التصميم التجريبي المستخدم هو تصميم القطع المنشقة مرة واحدة في ثلاث مكررات. بالنسبة لمعاملة ٧٥% من الجرعة الموصي بها من أسمدة NPK مع رش النباتات بخليط من (الحديد + السيلينيوم)، فقد حققت أعلى قيم معنوية لصفات (ارتفاع النبات ، عدد أوراق نبات-١، الوزن الطازج والجاف للأوراق و محتوي الكلوروفيل الكلي) ، المحصول (طول الثمار ، قطر الثمار ، عدد الثمار والمحصول الكلي, باستثناء عدد الثمار نبات-١ لم يحقق معنوية) مع جميع معدلات التسميد المعدني) والتركيب الكيماوي (محتوي النيتروجين والفوسفور والبوتاسيوم (%) في الاوراق ومعدل امتصاص النيتروجين والبوتاسيوم (جرام نبات-١) في أوراق الباذنجان بينما معدل امتصاص الفوسفور حقق نتيجة غير معنوية مقارنة بالنباتات غير المعامله وكذلك جودة الثمارمن حيث (البروتين الخام,الكربوهيدرات الكلية، الألياف الغذائية و فيتامين ج فيما عدا النترات و التي أعطت الاتجاه المعاكس). تم الحصول علي أعلي القيم لتركيز النترات في أوراق الباذنجان عند تطبيق رش الحديد مع ١٠٠% من الجرعة الموصي بها من أسمدة NPK. من ناحية أخرى، فإن المعاملة ١٠٠% من الجرعة الموصي بها من أسمدة NPK x مع خليط من (الحديد + السيلينيوم) أدت الي زيادة معنوية في محتوي الحديد والسيلينيوم في أوراق الباذنجان. ووفقا لذلك فان تسميد الباذنجان بمعدل ٧٥% من السماد المعدني NPK مع الرش بخليط من الحديد والسيلينيوم بمعدل ٣٠٠ ملجم لتر-١ و ٥ ملجم لتر-١ يعطي أعلي قيم معنوية لجميع صفات الباذنجان من (النمو والمحصول وجودته) تحت ظروف الدراسة.